CLAIMS

1. A storage-type water heater comprising:

a water tank comprising an inner surface and a vertical axis; and

a control system comprising

a first electric-resistance heating element coupled to the tank, the first heating element comprising a thermal surface disposed within the inner surface at a first location,

a second electric-resistance heating element coupled to the tank, the second heating element comprising a thermal surface disposed within the inner surface at a second location disposed vertically from the first location,

a first temperature sensor coupled to the tank and associated with the first heating element,

a second temperature sensor coupled to the tank and associated with the second heating element, and

a third temperature sensor coupled to the tank at a third location disposed vertically between the first and second locations.

2. A storage-type water heater as set forth in claim 1 wherein the first temperature sensor is disposed at a location vertically above the first heating element, and wherein the second temperature sensor is disposed at a location vertically above the second heating element.

3. A storage-type water heater as set forth in claim 2 wherein the first temperature sensor is disposed adjacent to the first heating element, and wherein the second temperature sensor is disposed adjacent to the second heating element.

4. A storage-type water heater as set forth in claim 1 wherein the first location is in a substantially lower portion of the tank and the second location is in a substantially higher portion of the tank, and wherein the third location is substantially between the first and second locations.

5. A storage-type water heater as set forth in claim 4 wherein the third location is in a vertically closer proximity to the second heating element.

6. A storage-type water heater as set forth in claim 1 wherein the first and second temperature sensors sense first and second temperatures, respectively, having a relation to the water temperature, and wherein the control system comprises a controller operable to receive the first and second temperatures and control the first and second heating elements based on the first and second temperatures.

7. A storage-type water heater as set forth in claim 6 wherein the third temperature sensor senses a third temperature having a relation to the water temperature, and wherein controller is further operable to determine a boost state based on the third temperature sensor.

8. A storage-type water heater as set fourth in claim 6 wherein the control system further comprises a programmable controller.

9. A storage-type water heater as set forth in claim 6 wherein the programmable controller controls the first heating element based on the first temperature and the second heating element based on the second temperature, and wherein the programmable controller determines a boost state based on the third temperature sensor.

10. A storage-type water heater as set forth in claim 1 wherein the storage-type water heater further comprises a cold-water inlet and a hot-water outlet, and wherein the control system further comprises a fourth temperature sensor coupled to the tank at a fourth location associated with the hot water outlet.

11. A storage-type water heater as set forth in claim 6 wherein the fourth temperature sensor senses a fourth temperature having a relation to the water temperature, and wherein the control system further comprises a high-temperature-limit relay switch to interrupt power to the first and second heating elements if the fourth temperature exceeds a set-point temperature and zero or more other conditions exist.

12. A storage-type water heater as set forth in claim 1 wherein the water heater further comprises a jacket surrounding at least a portion of the tank and wherein the control system further comprises a moisture sensor disposed between the tank and the jacket.

13. A storage-type water heater as set forth in claim 1 wherein the water heater further comprises a drip pan disposed beneath at least a portion of the tank, and the wherein the control system further comprises a moisture sensor disposed between the tank and the drip pan.

14. A method of heating water stored in a water tank of a storage-type water heater comprising

a first electric-resistance heating element comprising a thermal surface disposed within an inner surface of the tank at a first location,

a second electric-resistance heating element comprising a thermal surface disposed within the inner surface of the tank at a second location disposed vertically above the first location, and

first and second temperature sensors associated with the first and second heating elements, respectively, the method comprising:

sensing a first temperature with the first temperature sensor;

sensing a second temperature with the second temperature sensor;

preventing power to the second heating element and controllably providing power to the first heating element if the first temperature is below a first set point, the second temperature is above a second set point, and zero or more other conditions exist;

preventing power to the first heating element and controllably providing power to the second heating element if the second temperature is below a second set point and zero or more other conditions exist; and

preventing power to the first and second heating elements if the first and second temperatures are above the first and second set points, respectively, and zero or more other conditions exist.

15. A method as set forth in claim 14 wherein the first and second set points are the same.

16. A method as set forth in claim 14 wherein the water heater further comprises a third temperature sensor coupled to the tank at a third location disposed vertically between the first and second locations, wherein the acts of preventing power to the second heating element and controllably providing power to the first heating element and preventing power to the first heating element and controllably providing power to the second heating element occur during normal operation, and wherein the method further comprises:

sensing a third temperature with the third temperature sensor;

ceasing normal operation if the third temperature is below a third set point and zero or more other conditions exist; and

entering boost operation if the third temperature is below a third set point and zero or more other conditions exist.

17. A method as set forth in claim 16 wherein the act of entering boost operation comprises controllably providing power to the second heating element when the third temperature is below a third set point.

18. A method as set forth in claim 17 wherein the act of entering boost operation further comprises preventing power to the first heating element.

19. A method as set forth in claim 16 wherein the water heater further comprises a fourth temperature sensor coupled to the tank at a fourth location associated with a hot water outlet of the tank, and wherein the method comprises:

sensing a fourth temperature with the fourth temperature sensor;

ceasing normal operation if the fourth temperature sensor is above a fourth set point and zero or more other conditions exist; and

preventing power to the first and second heating elements after the fourth temperature sensor is above a fourth set point and zero or more other conditions exist.

20. A method as set forth in claim 16 and further comprising:
manually ceasing normal operation; and
manually entering boost operation.

21. A method as set forth in claim 16 wherein the act of manually entering boost operation comprises controllably providing power to the second heating element and preventing power to the first heating element.

22. A method as set forth in claim 16 wherein the third set point is greater than the second set point.

23. A storage-type water heater comprising:

a water tank for storing water;

a cold-water inlet and a hot-water outlet, both of which enter the tank;

an electrically-operated solenoid valve coupled to the cold-water inlet to control the flow of water into the water tank;

a jacket surrounding at least a portion of the tank;

a control system comprising a moisture sensor disposed between the tank and the jacket, and being operable to control the solenoid valve to prevent water from entering the tank if the moisture sensor generates a moisture value greater than a threshold and zero or more other conditions exist.

24. A storage-type water heater as set forth in claim 23 wherein the water heater further comprises a drip pan disposed between the tank and the jacket, wherein the moisture sensor is coupled to the drip pan, and wherein the moisture sensor senses moisture collected by the drip pan.

25. A storage-type water heater as set forth in claim 24 wherein the tank comprises a top and a bottom, and wherein the drip pan is disposed between the bottom of the tank and the jacket.

26. A storage-type water heater as set forth in claim 25 wherein the control system further comprises a second moisture sensor disposed between the top of the tank and the jacket, and wherein the control system is further operable to prevent the heating element from heating the tank if the second moisture sensor generates a moisture value greater than a second threshold and zero or more other conditions exist.

27. A storage-type water heater as set forth in claim 26 wherein the cold-water inlet and hot-water outlet enter the top of the water tank, and wherein the second moisture sensor is disposed between the cold-water inlet and the hot-water outlet.

28. A storage-type water heater as set forth in claim 23 wherein the tank comprises a top and a bottom, wherein the first moisture sensor is disposed between the bottom of the tank and the jacket, wherein the control system comprises a second moisture sensor disposed between the top of the tank and the jacket, and wherein the control system is further operable to prevent the heating element from heating the tank if the second moisture sensor generates a moisture value greater than a second threshold and zero or more other conditions exist.

29. A storage-type water heater as set forth in claim 28 wherein the water heater further comprises insulation disposed between at least one of the bottom of the tank and the jacket and the top of the tank and the jacket, and wherein at least one of the moisture sensors is disposed in the insulation.

30. A method of controlling a storage-type water heater comprising

a water tank comprising an inner surface

an electric-resistance heating element comprising a thermal surface disposed within the inner surface at a first location,

a second electric-resistance heating element comprising a thermal surface disposed within the inner surface at a second location, and

a control system to operate the first and second heating elements, the method comprising:

controllably providing power to the first and second heating elements to heat water stored in the water tank;

detecting the failure of one of the first and second heating elements;

if detecting the failure of one of the first and second heating elements and zero or more other conditions exist,

preventing power to the failed heating element; and

controllably providing power to the non-failed heating element to heat water stored in the water tank.

31. A method as set forth in claim 30 and further comprising:

if detecting the failure of one of the first and second heating elements and zero or more other conditions exist,

issuing an alarm.

32. A method as set forth in claim 30 wherein the control system comprises at least one temperature sensor and at least one current sensor associated with the first and second heating elements, wherein the method further comprises sensing at least one temperature with the at least one temperature sensor, wherein the act of controllably providing power to the first and second heating elements is based on the sensed at least one temperature, and wherein the act of detecting the failure comprises sensing a decrease in current to at least one of the first and second heating elements.

33. A method as set forth in claim 30 wherein the control system comprises first and second temperature sensors associated with the first and second heating elements and first and second current sensors associated with the first and second heating elements, respectively, wherein the method further comprises sensing a first temperature with the first temperature sensor and sensing a second temperature with the second temperature sensor, wherein the act of controllably providing power to the first and second heating elements is based on the first and second temperatures, and wherein the act of detecting the failure comprises sensing a decrease in one of a first and second current sensed by the first and second current sensors, respectively.

34. A method as set forth in claim 33 wherein the act of controllably providing power to the first and second heating elements comprises controllably providing power to the first heating element, and wherein the act of sensing a first current occurs during the act of providing power to the first heating element.

35. A method as set forth in claim 34 wherein the act of detecting the failure further comprises determining a failure if the first current is less than a threshold current and zero or more other conditions exist, the threshold current indicating insufficient current is flowing to the first heating element.

36. A method as set forth in claim 34 wherein the act of detecting the failure comprises determining a first resistance of the first heating element based on the first current, determining a failure for the first heating element if the first resistance is greater than a threshold and zero or more other conditions exist.

37. A method as set forth in claim 36 wherein the threshold indicates a first heating circuit comprising the first heating element has an open circuit condition.

38. A method as set forth in claim 36 wherein the threshold indicates a dry-fire condition for the first heating element.

39. A method as set forth in claim 38 wherein the act of controllably providing power to the non-failed element comprises preventing power to both the failed heating element and the non-failed heating element if the detected failure is a dry-fire condition and zero or more other conditions exist.

40. A method as set forth in claim 33 wherein the act of controllably providing power to the first and second heating elements comprises controllably providing power to the first heating element, wherein the act of sensing a first temperature occurs during the act of providing power to the first heating element, and wherein the act of sensing a first current occurs during the act of providing power to the first heating element.

41. A method as set forth in claim 40 wherein the method further comprises sensing a third temperature with the first temperature sensor during the act of controllably providing power to the first heating element, wherein the act of detecting the failure further comprises calculating a temperature rise with the first and third temperatures and determining a failure for the first heating element if the first current is greater than a threshold current, the temperature rise is less than a threshold temperature rise, and zero or more other conditions exist.

42. A method as set forth in claim 30 wherein the control system comprises a first temperature sensor associated with the first heating element, wherein the act of controllably providing power to the first and second heating elements comprises controllably providing power to the first heating element, wherein the method further comprises sensing first and second temperatures with the first heating element, the second temperature sensed after the first temperature, and wherein the act of detecting the failure comprises calculating a temperature rise with the first and second temperatures, comparing the temperature rise to a threshold temperature rise, the threshold temperature rise indicating scale buildup, and determining a failure for the first heating element if scale buildup occurs and zero or more other conditions exist.

43. A method as set forth in claim 31 wherein the control system comprises a current sensor associated with the first heating element, wherein the act of controllably providing power to the first and second heating elements comprises controllably providing power to the first heating element, wherein the method further comprises sensing first and second currents with the first current sensor, the second current sensed after the first current, and wherein the act of detecting the failure comprises calculating first and second resistance values with the first and second temperatures, respectively, calculating a resistance rate change with the first and second resistance values, comparing the resistance rate change to a threshold resistance rate change, the threshold resistance rate change indicating scale buildup, and determining a failure for the first heating element if scale buildup occurs and zero or more other conditions exist.